Robert C. Colwell, Reg. No. 27,431   (650) 326-2400
Applicant: Aki TOMITA
Title: DATA I/O SYSTEM USING A PLURALITY OF MIRROR...
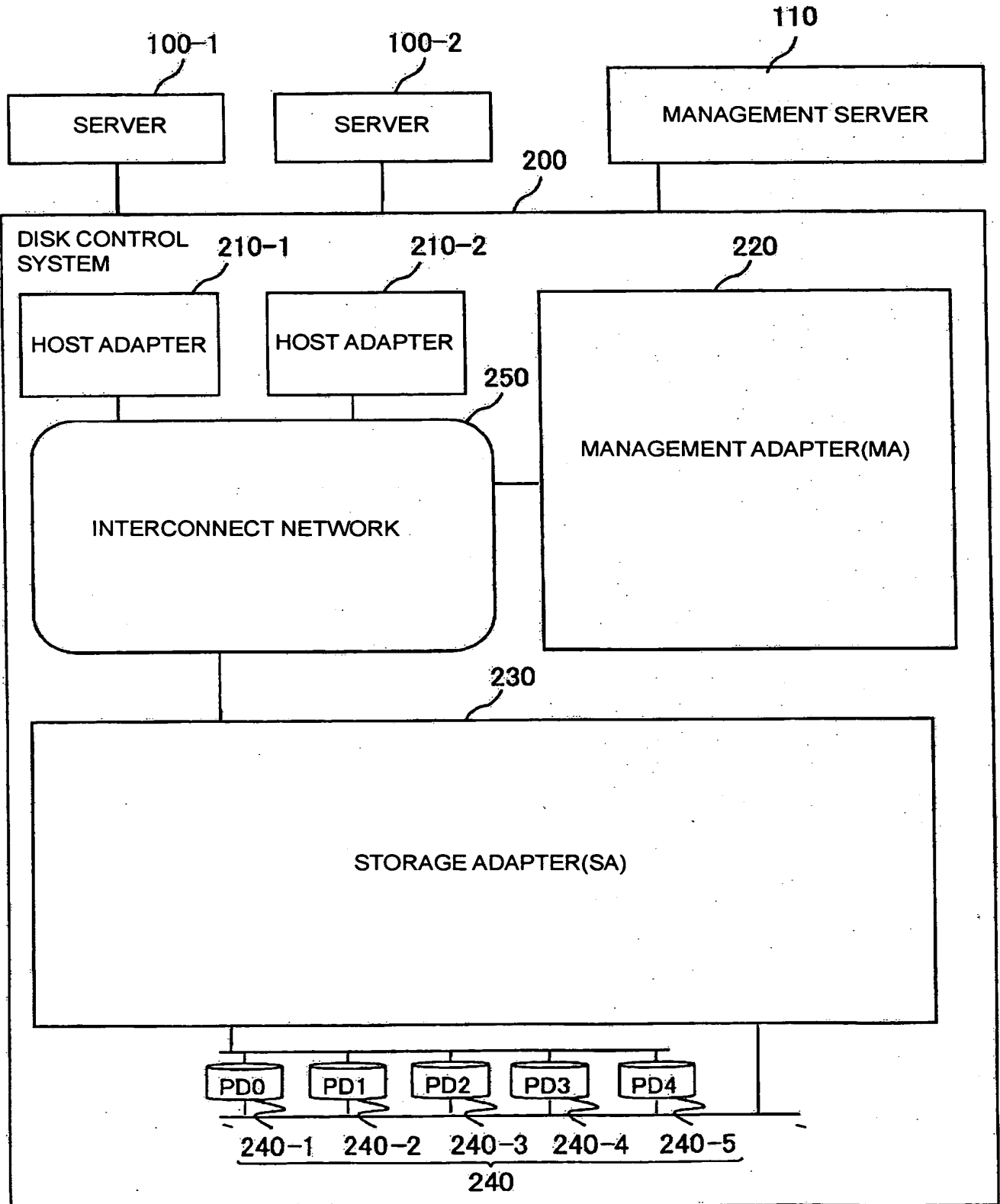Atty Docket No. 16869K-109000US
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FIG. 1

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HOST ADAPTER — 210

214 — MICROPROCESSOR

211 — COMMUNICATION INTERFACE

212 — LOCAL MEMORY

231

213 — NON-VOLATILE MEMORY

215 — I/O PROCESSOR

FIG. 2

STORAGE ADAPTER — 230

234 — MICROPROCESSOR

231 — I/O PROCESSOR

232 — LOCAL MEMORY

236

233 — NON-VOLATILE MEMORY

235 — DISK CONTROLLER

FIG. 3

MANAGEMENT ADAPTER — 220

221 — MICROPROCESSOR

223 — INTERNAL COMMUNICATION INTERFACE

222 — MEMORY

235

FIG. 4

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110

MANAGEMENT SERVER

CPU ~111

112

118   114

STORAGE MEDIUM → STORAGE MEDIA READING DEVICE

MEMORY

115 ~ INPUT DEVICE

116 ~ OUTPUT DEVICE

PORT ~113

STORAGE DEVICE ~117

FIG. 5

Robert C. Colwell, Reg. No. 27,431   (650) 326-2400
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100-1
SERVER

100-2
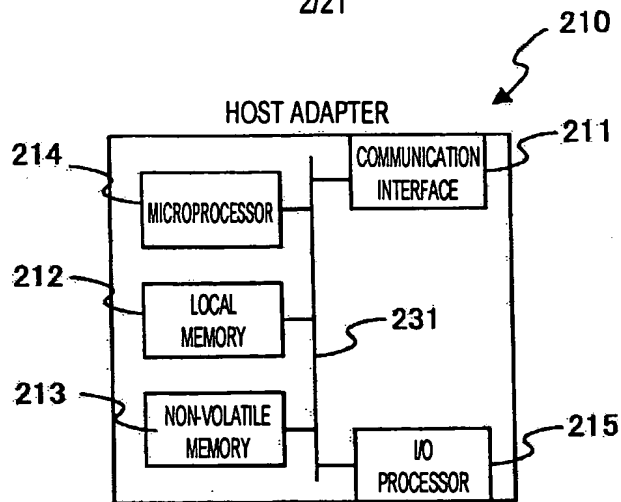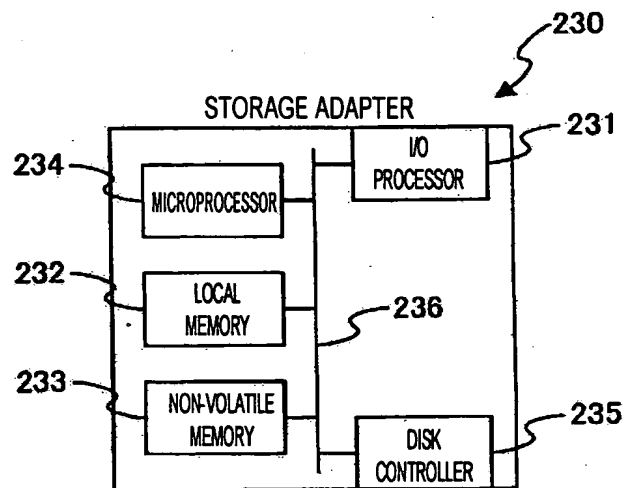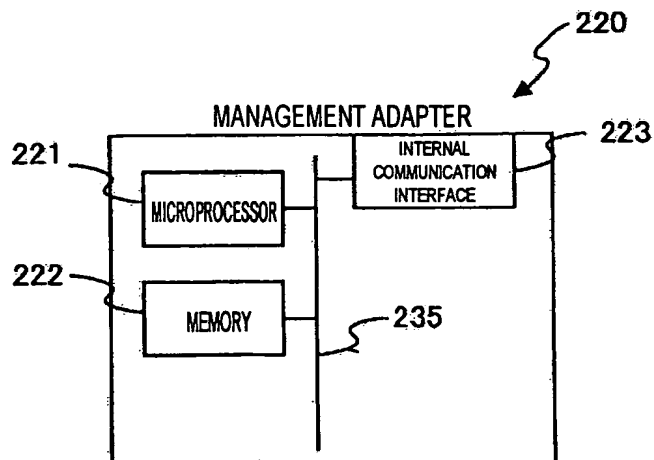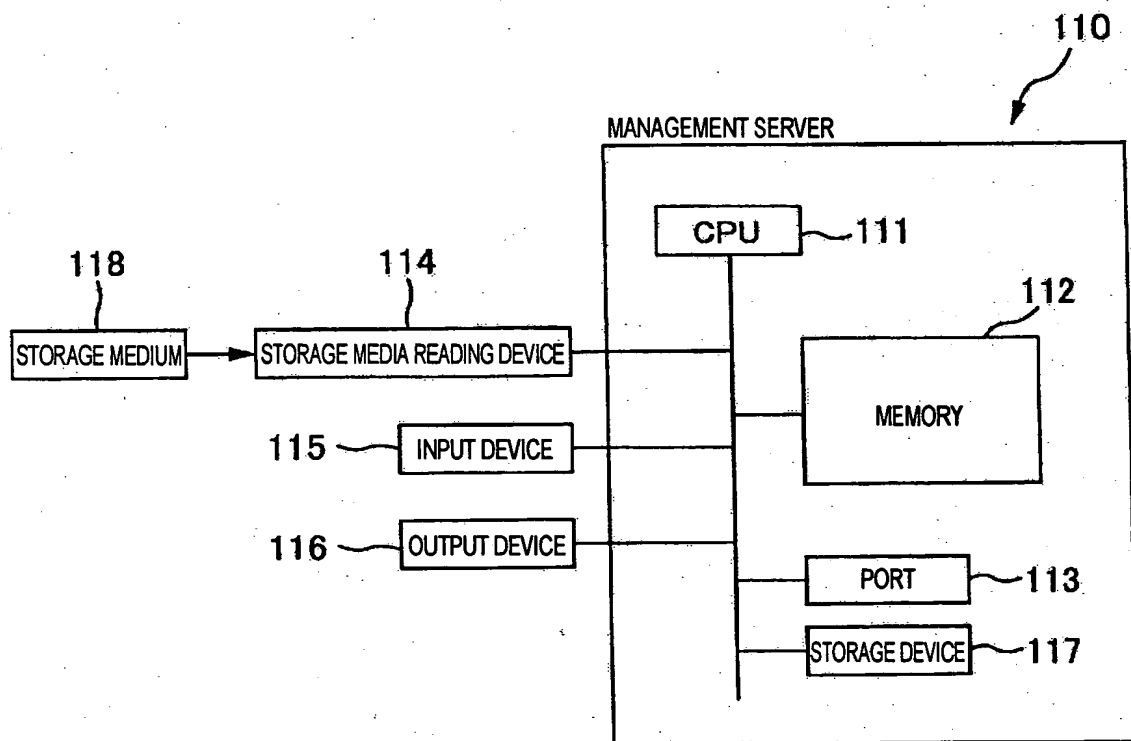SERVER

110
MANAGEMENT SERVER
610
S-VOL GROUP SETTING UNIT

200

DISK CONTROL SYSTEM

210-1
HOST ADAPTER

210-2
HOST ADAPTER

250

220
MANAGEMENT ADAPTER(MA)

620
S-VOL GROUP MANAGEMENT UNIT

900
S-VOL GROUP MANAGEMENT TABLE

INTERCONNECT NETWORK

230
STORAGE ADAPTER(SA)

1200
S-VOL MANAGEMENT TABLE

630
S-VOL MANAGEMENT UNIT

650
S-VOL ERROR PROCESS UNIT

640
S-VOL R/W PROCESS UNIT

1300
INCREMENTS MANAGEMENT TABLE

PD0   PD1   PD2   PD3   PD4

240-1   240-2   240-3   240-4   240-5

240

FIG. 6

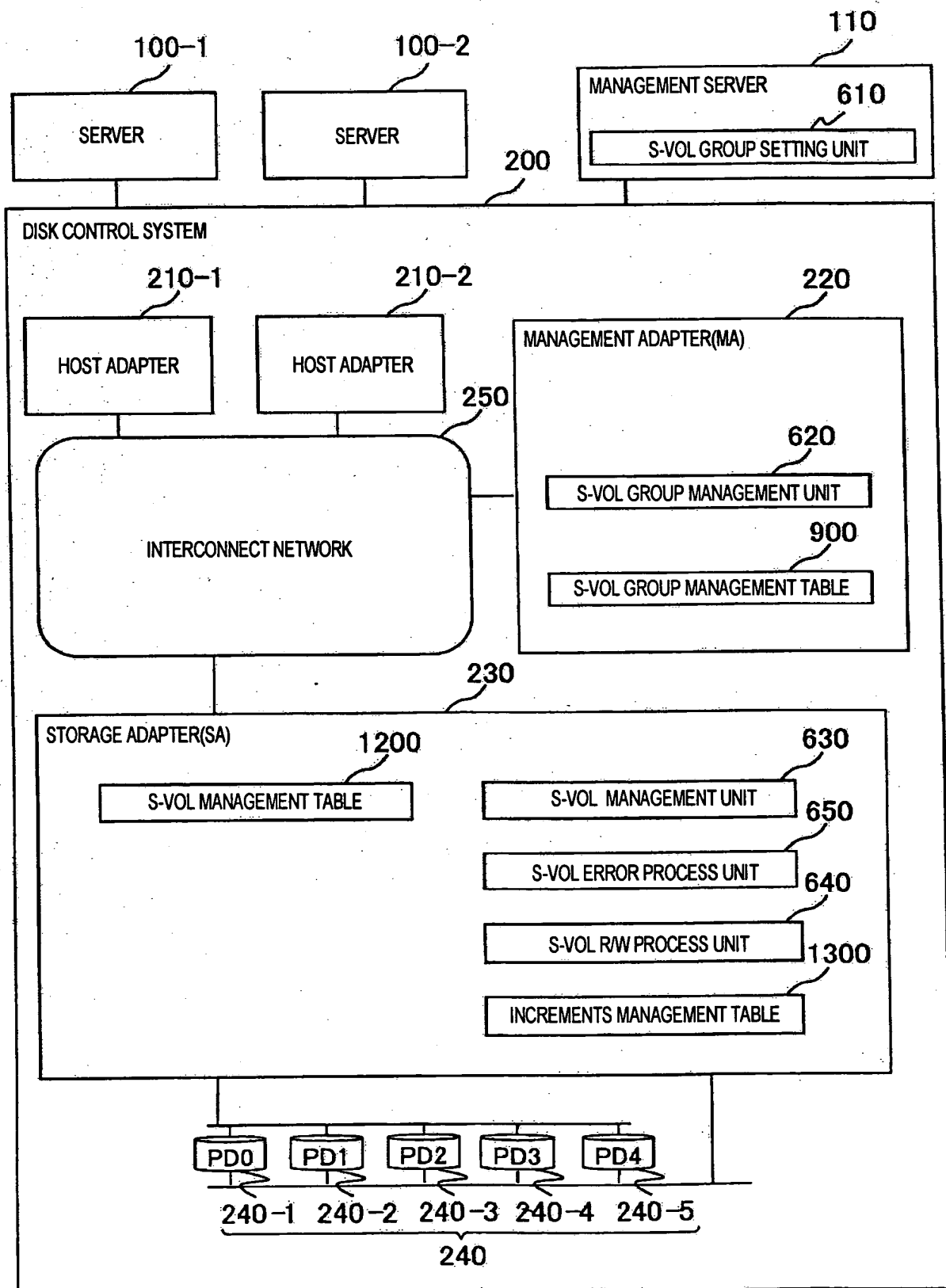Robert C. Colwell, Reg. No. 27,431   (650) 326-2400
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Atty Docket No. 16869K-109000US
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700

COPY SOURCE-DESTINATION TABLE

COPY SOURCE LU (LUN)	COPY DESTINATION LU (LUN)
1	10
2	11
3	12
4	13
5	14

FIG. 7

Robert C. Colwell, Reg. No. 27,431   *(650) 326-2400*

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S-VOL GROUP OPERATION COMMAND (MANAGEMENT SERVER/MA)

COMMAND ID	COMMAND SPECIFIC FIELD

820   830
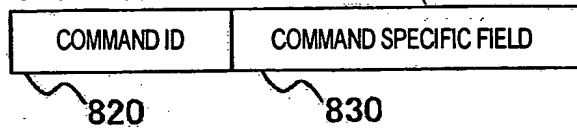
0 : S-VOL GROUP INITIALIZATION

1 : RESTORE

3 : QUERY (S-VOL ATTRIBUTE/SPARE S-VOL ATTRIBUTE)

FIG. 8A

S-VOL GROUP INITIALIZATION COMMAND 810-1

0	GROUP ID	S-VOL ATTRIBUTE LIST	NUMBER OF SPARES

820   831   832   833

830

S-VOL ATTRIBUTE LIST 832

LID	ATTRIBUTE (RO/RW)

834   835

FIG. 8B

RESTORE COMMAND 810-2

1	LID	BIDs

820   836   837

830

FIG. 8C

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Applicant: Aki TOMITA
Title: DATA I/O SYSTEM USING A PLURALITY OF MIRROR...
Atty Docket No. 16869K-109000US
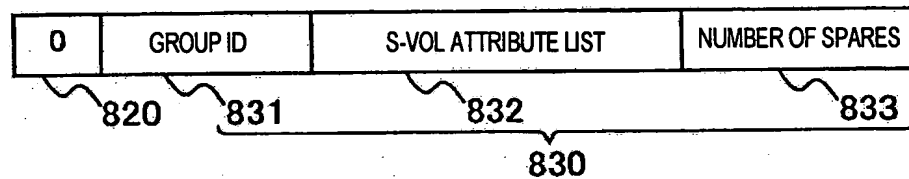**Sheet 7 of 21**

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S-VOL GROUP MANAGEMENT TABLE   900

GROUP ID (GrpID)	LOGICAL VOLUME ID (LID)	LOGICAL REGION ATTRIBUTE (Attr)	PHYSICAL VOLUME ID (PID)	RECOVERY ID (RLID)
	901	902	903	904	905

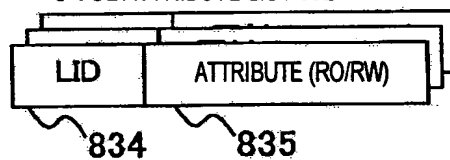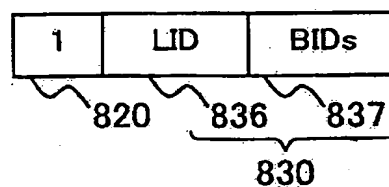| GROUP ID (GrpID)	LOGICAL VOLUME ID (LID)	LOGICAL REGION ATTRIBUTE (Attr)	PHYSICAL VOLUME ID (PID)	RECOVERY ID (RLID)
	LV0	RO	PD0	
G0	LV1	RO	PD1	
	LV2	RW	PD2	DLV2
	S0	RO	PD3	
	DLV2	RW	PD4	

FIG. 9

Robert C. Colwell, Reg. No. 27,431   (650) 326-2400

Applicant: Aki TOMITA
Title: DATA I/O SYSTEM USING A PLURALITY OF MIRROR...
Atty Docket No. 16869K-109000US
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S-VOL GROUP SETTING UNIT 610   S-VOL GROUP MANAGEMENT UNIT 620

S1010

SEND
S-VOL GROUP INITIALIZATION
COMMAND 810-1

S1020

RECEIVE
S-VOL GROUP INITIALIZATION
COMMAND 810-1

S1021

SET S-VOL GROUP MANAGEMENT TABLE 900

S1022

ASSIGN PHYSICAL REGION TO
S-VOL/SPARE S-VOL/INCREMENTS-VOLUME

S1023

SEND REPLY TO
S-VOL GROUP SETTING UNIT 610

S1024

SEND
S-VOL INITIALIZATION COMMAND 1150-1 TO
S-VOL MANAGEMENT UNIT 630

END

FIG. 10

Robert C. Colwell, Reg. No. 27,431   *(650) 326-2400*

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Atty Docket No. 16869K-109000US
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S-VOL OPERATION COMMAND (SA/MA) 1150

COMMAND ID	COMMAND SPECIFIC FIELD

1160   1170

0: S-VOL INITIALIZATION

1: PID CHANGE

2: QUERY (ATTRIBUTE/PID/ACCESS FREQUENCY)

3: RESTORE

FIG. 11A

S-VOL INITIALIZATION COMMAND 1150-1

0	VOLUME LIST

1171   1172

VOLUME LIST 1172

LID	ATTRIBUTE	PID	RLID

1173   1174   1175   1176

FIG. 11B

S-VOL RESTORE COMMAND 1150-2

3	LID	BIDs	RLID

1177   1178   1179   1180

FIG. 11C

Robert C. Colwell, Reg. No. 27,431   (650) 326-2400
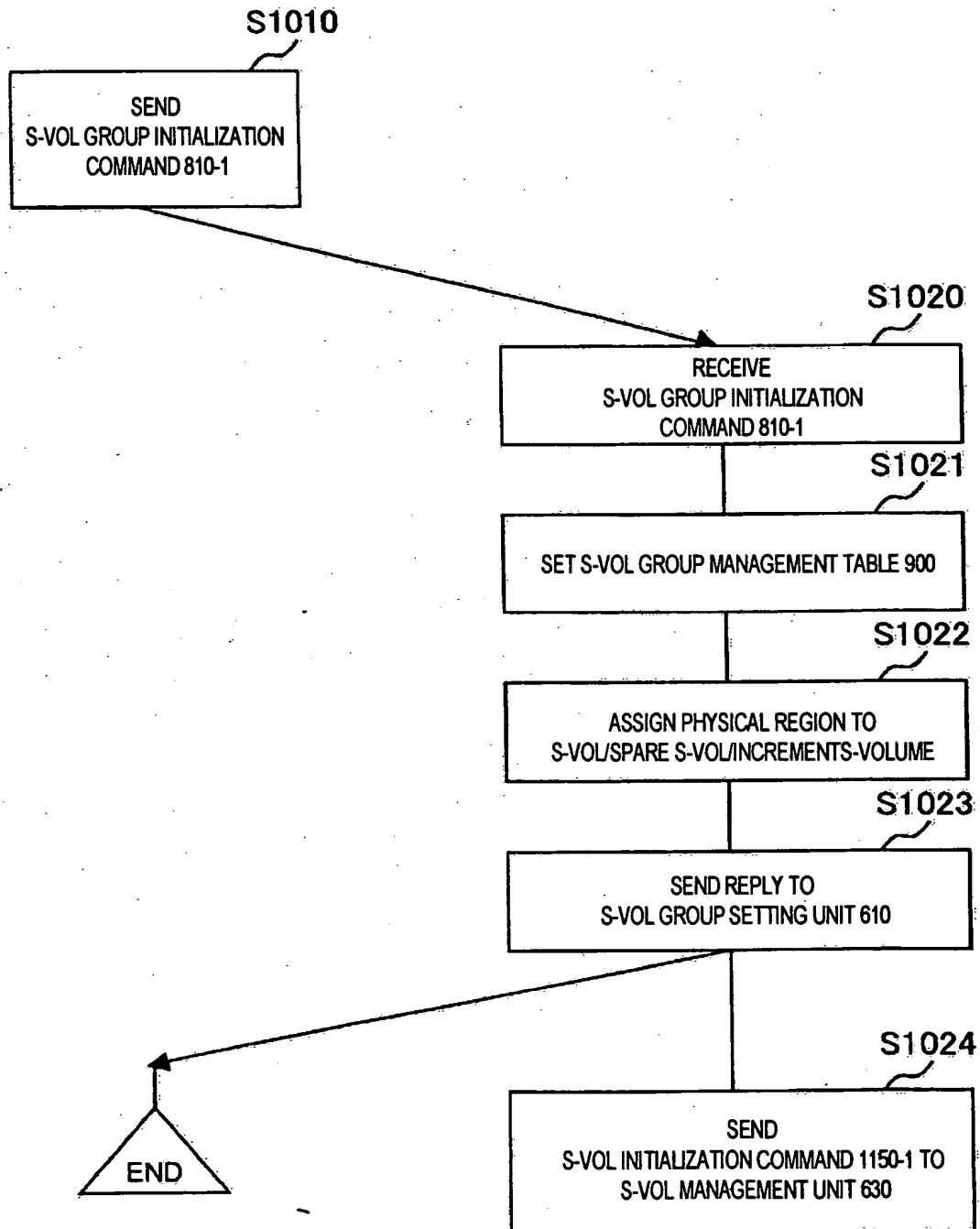Applicant: Aki TOMITA
Title: DATA I/O SYSTEM USING A PLURALITY OF MIRROR...
Atty Docket No. 16869K-109000US
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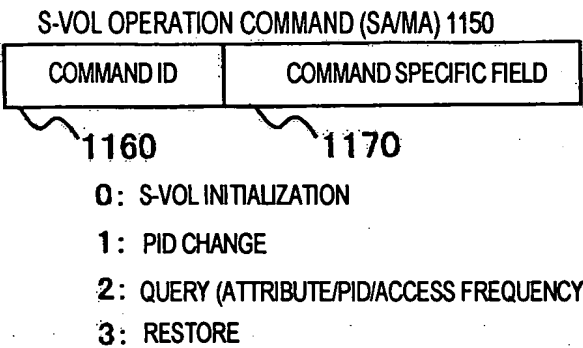S-VOL MANAGEMENT TABLE   1200

LOGICAL VOLUME ID (LID)	LOGICAL VOLUME ATTRIBUTE (Attr)	PHYSICAL VOLUME ID (PID)	RECOVERY LID (RLID)	ACCESS FREQUENCY (Freq)
1201	1202	1203	1204	1205
LV0	RO	PD0		
LV1	RO	PD1		
LV2	RW	PD2	DLV2	
S0	—	PD3		
DLV2	RW	PD4		

FIG. 12

INCREMENTS MANAGEMENT TABLE   1300

INCREMENTS LID (DLID)	BLOCK ID (BID)
1351	1352
DLV2	

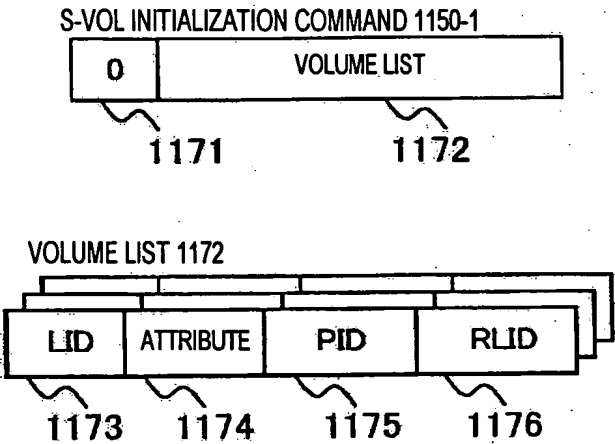FIG. 13

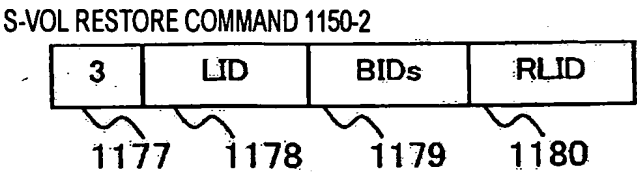Robert C. Colwell, Reg. No. 27,431   (650) 326-2400
Applicant: Aki TOMITA
Title: DATA I/O SYSTEM USING A PLURALITY OF MIRROR...
Atty Docket No. 16869K-109000US
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S-VOL GROUP MANAGEMENT UNIT 620   S-VOL MANAGEMENT UNIT 630
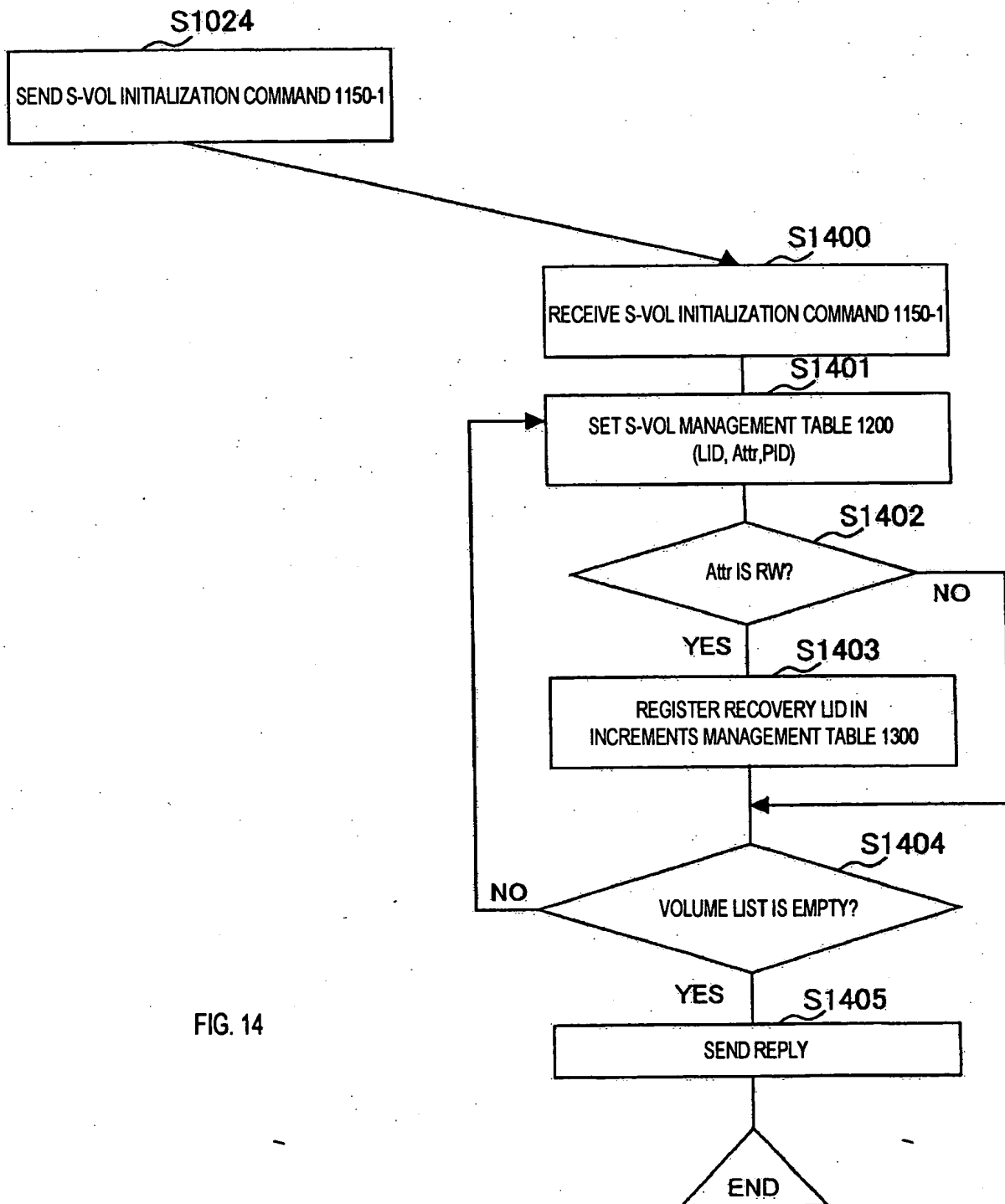
S1024

SEND S-VOL INITIALIZATION COMMAND 1150-1

S1400

RECEIVE S-VOL INITIALIZATION COMMAND 1150-1

S1401

SET S-VOL MANAGEMENT TABLE 1200
(LID, Attr, PID)

S1402

Attr IS RW?

NO

YES   S1403

REGISTER RECOVERY LID IN
INCREMENTS MANAGEMENT TABLE 1300

S1404

NO   VOLUME LIST IS EMPTY?

YES   S1405

SEND REPLY

END

FIG. 14

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Atty Docket No. 16869K-109000US
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S-VOL R/W PROCESS UNIT 640 (READ PROCESS)

S1500

RECEIVE READ REQUEST FOR S-VOL (LV0)

S1501

READ FROM LV0

S1502

DRIVE ERROR IS DETECTED? — YES

NO

S1510

NOTIFY S-VOL ERROR PROCESS UNIT 650 OF READ ERROR

S1511

RECOVERY IS SUCCESSFUL? — NO

YES   S1512

REREAD FROM LV0

S1503

ADD 1 TO Freq OF S-VOL MANAGEMENT TABLE 1200

S1504

SEND READ REPLY

END

FIG. 15

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S-VOL ERROR PROCESS UNIT 650   S-VOL GROUP MANAGEMENT UNIT 620

S1510

SEND READ ERROR NOTIFICATION

S1600

RECEIVE READ ERROR NOTIFICATION

S1601

EXECUTE READ ERROR PROCESS 1700

S1602

SEND RECOVERY RESULT

S1611

RECEIVE RECOVERY RESULT

S1612

RECOVERY IS SUCCESSFUL?   NO

YES   **S1620**

RESET PID OF LVO

S1621

RECOVERY VOLUME IS S-VOL?   NO

S1622   YES   **S1623**

SET SELECTED S-VOL IN RLID   DELETE SELECTED SPARE S-VOL

S1624   **S1613**

NOTIFY S-VOL R/W PROCESS UNIT 900 OF RECOVERY SUCCESS   NOTIFY S-VOL R/W PROCESS UNIT 900 OF RECOVERY FAILURE

END   END

FIG. 16
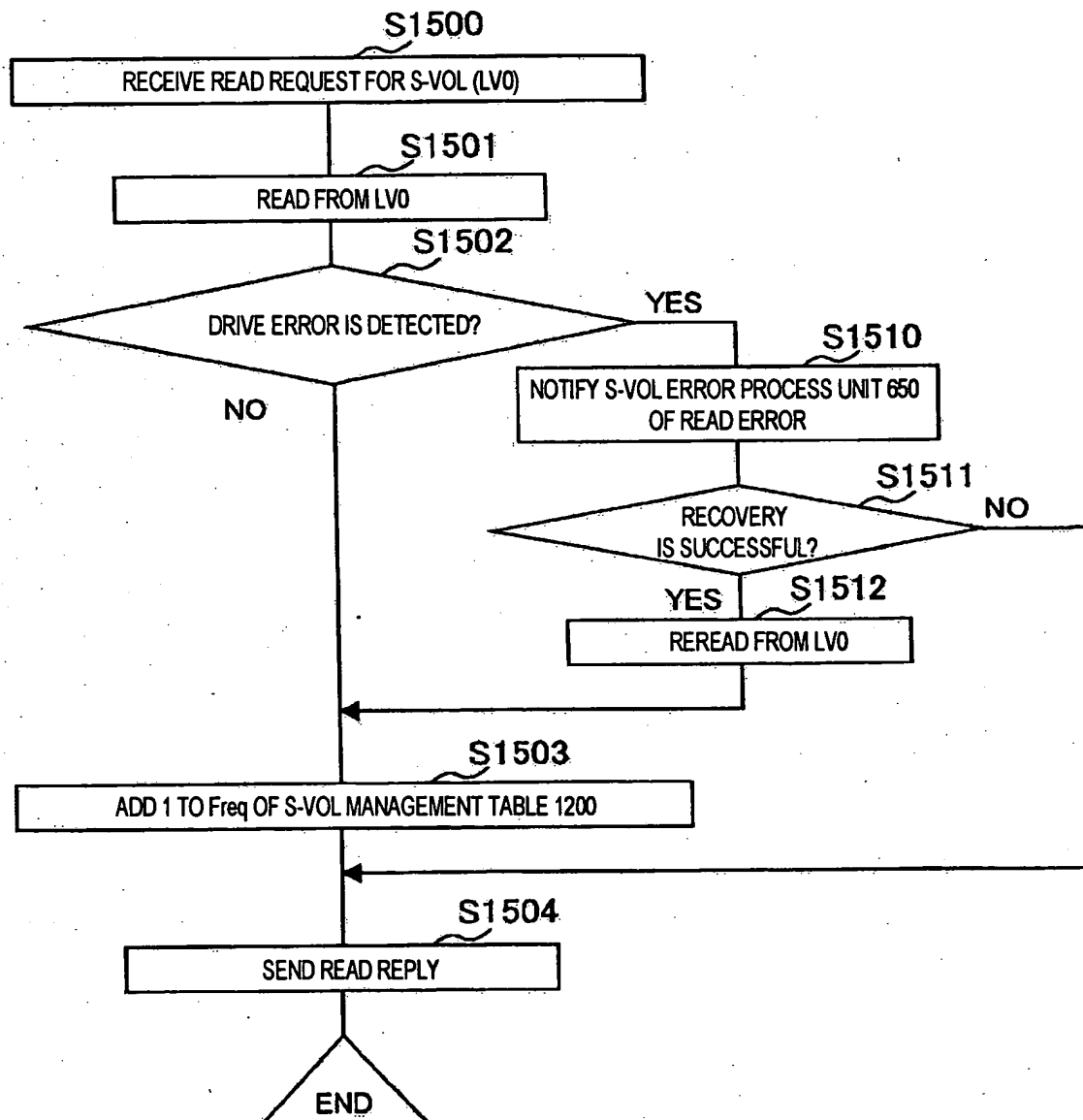
Robert C. Colwell, Reg. No. 27,431   *(650) 326-2400*

Applicant: Aki TOMITA
Title: DATA I/O SYSTEM USING A PLURALITY OF MIRROR...
Atty Docket No. 16869K-109000US
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S-VOL READ ERROR PROCESS

S1701

SPARE S-VOL
IS PRESENT?

YES

NO   S1702   S1710

RO S-VOL
IS PRESENT?   NO   CHANGE PID TO PID OF SPARE S-VOL

S1703   S1711

YES   NOTIFY READ ERROR   DELETE SPARE S-VOL

S1704

INQUIRE SA 230 FOR Freq OF RO S-VOL

S1705

SELECT RO S-VOL BASED ON Freq

S1706

CHANGE PID TO PID OF SELECTED S-VOL

S1707

REGISTER
LID OF SELECTED S-VOL IN RLID

END

–FIG. 17

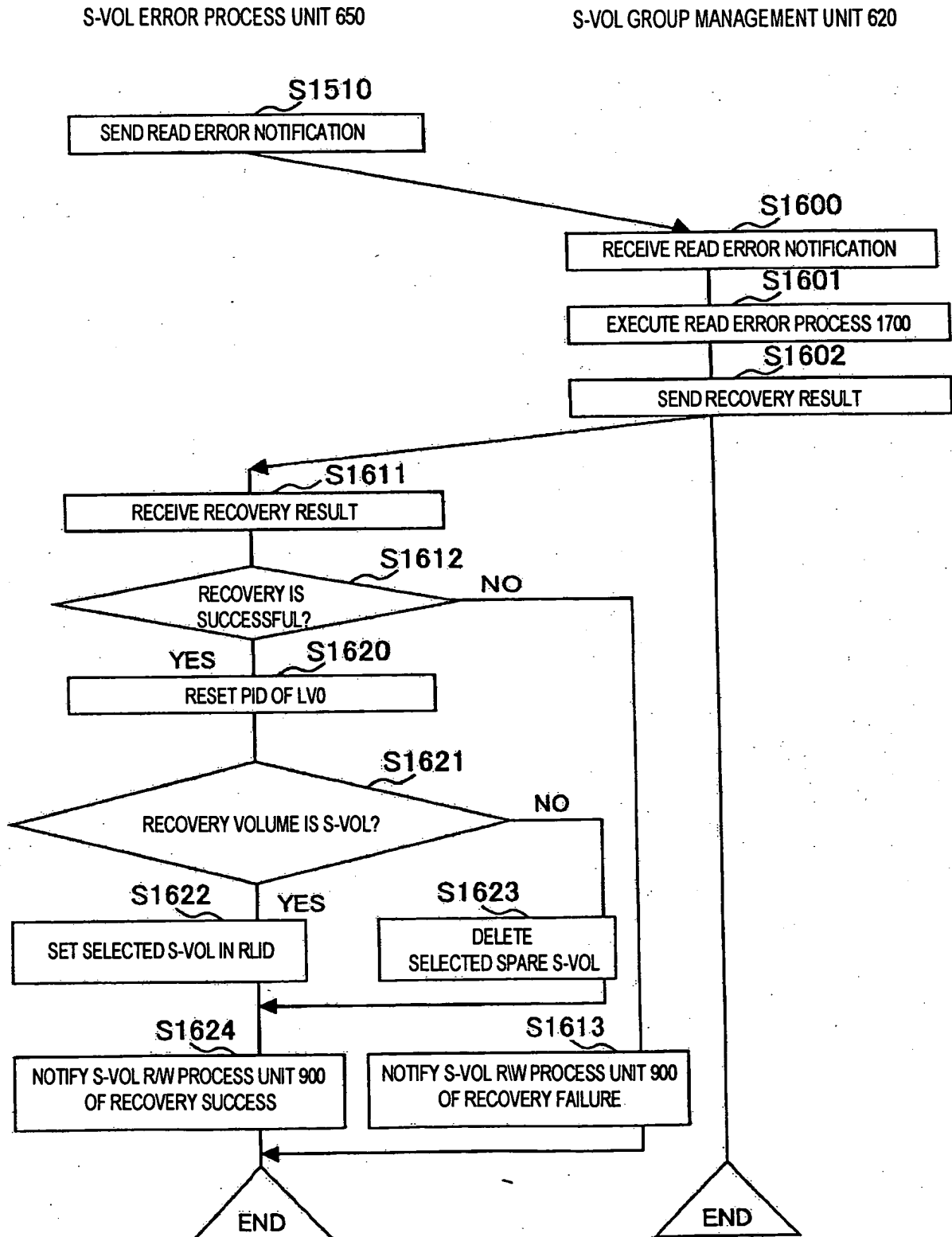*Robert C. Colwell, Reg. No. 27,431*   *(650) 326-2400*
Applicant: Aki TOMITA
Title: DATA I/O SYSTEM USING A PLURALITY OF MIRROR...
Atty Docket No. 16869K-109000US
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S-VOL READ/WRITE PROCESS UNIT (WRITE PROCESS)

S1800

RECEIVE WRITE REQUEST FOR RW S-VOL (LV2)

WRITE REQUEST

| wbid | Offset | WRITE DATA |

S1801

Attr IS D-RW?   YES

NO   S1810   S1802

EXECUTE INCREMENTS WRITE PROCESS

WRITE NORMALLY

S1811

WRITE ERROR HAS HAPPENED?   NO

YES   S1820   S1812

NOTIFY S-VOL ERROR PROCESS UNIT 800 OF WRITE ERROR

ADD 1 TO Freq AND SEND WRITE REPLY (SUCCESS)

S1821

YES   RECOVERY IS SUCCESSFUL?

NO   S1822

SEND WRITE REPLY (FAILURE)

END

FIG. 18

Robert C. Colwell, Reg. No. 27,431   (650) 326-2400
Applicant: Aki TOMITA
Title: DATA I/O SYSTEM USING A PLURALITY OF MIRROR...
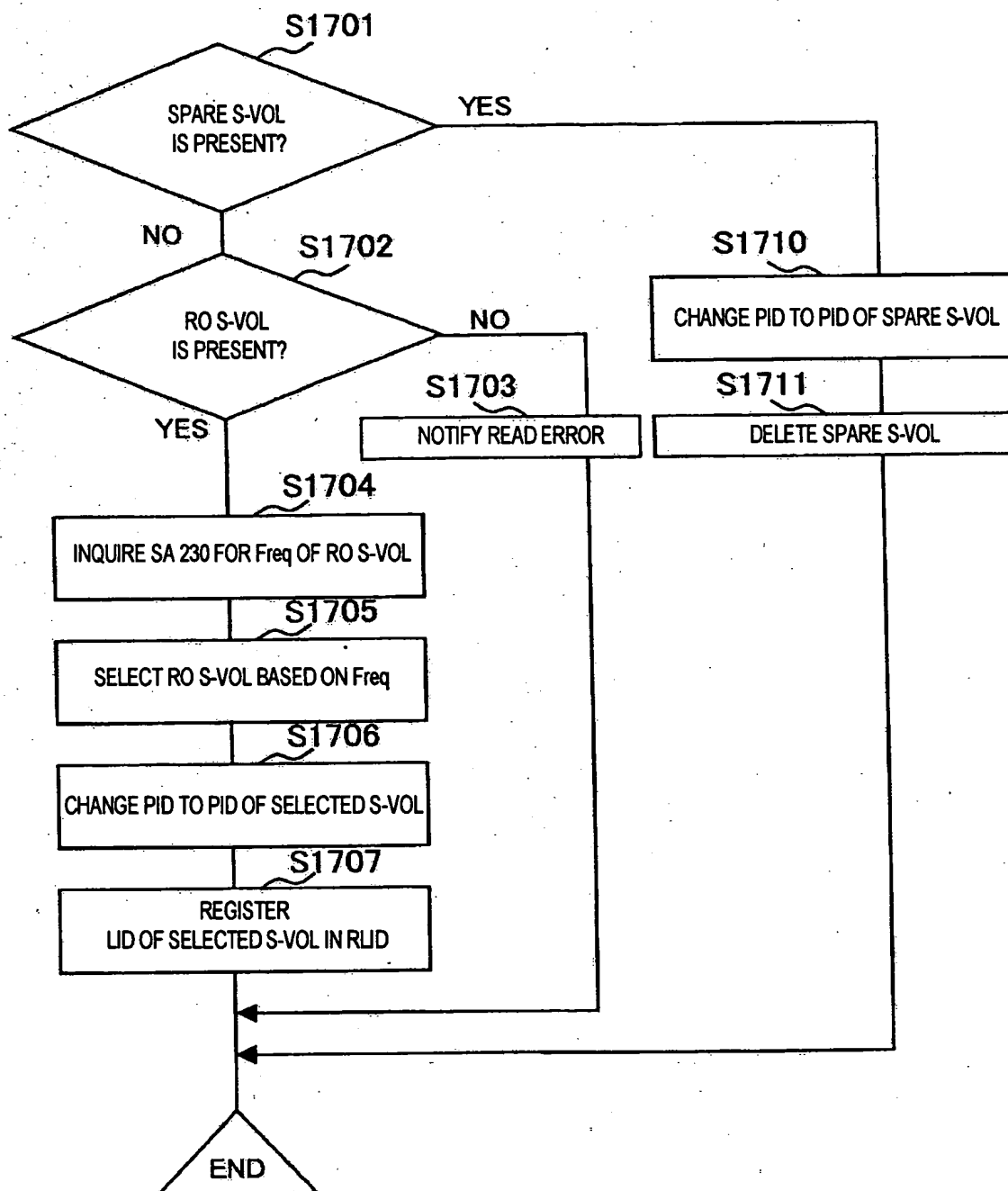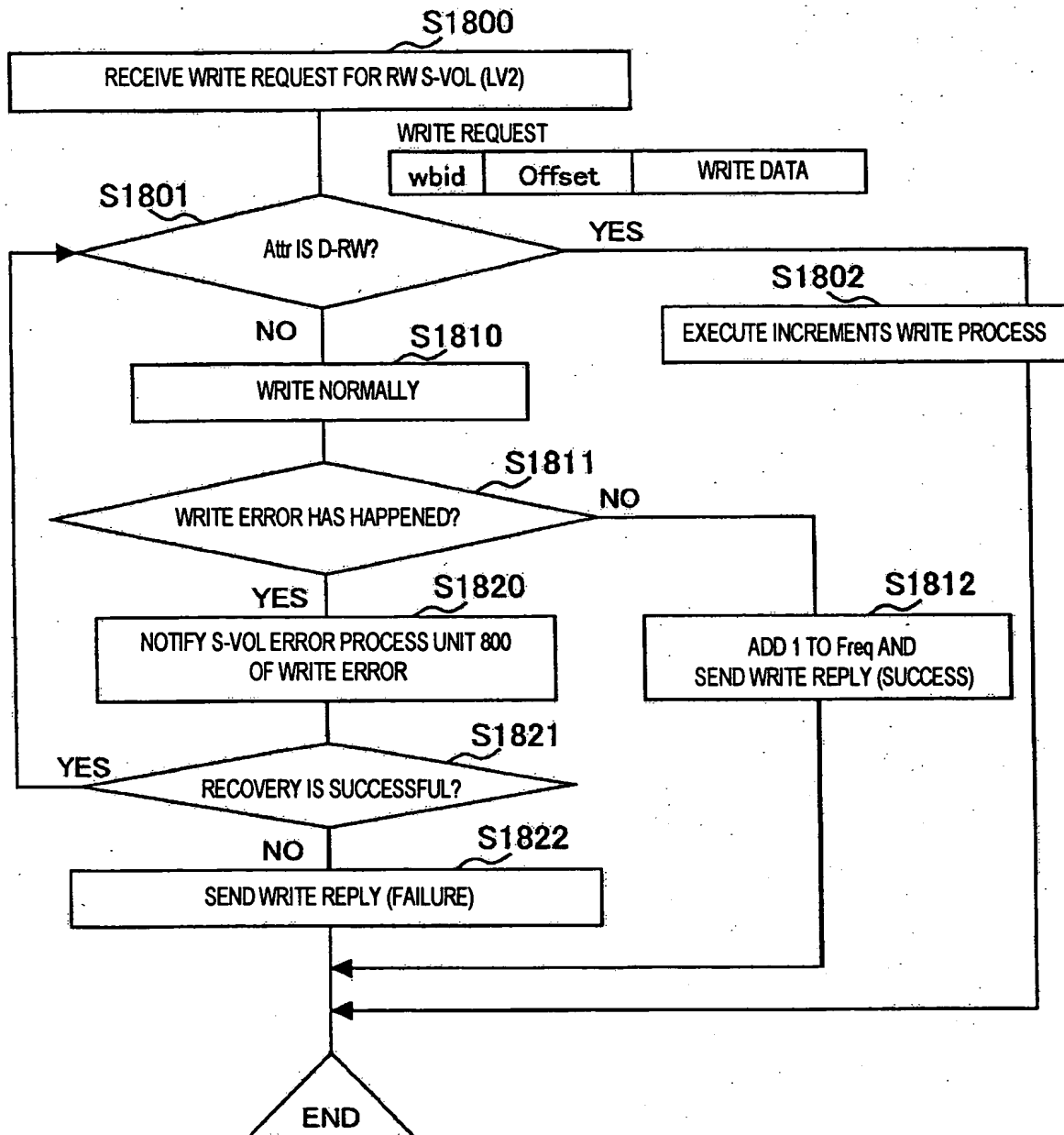Atty Docket No. 16869K-109000US
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S-VOL READ/WRITE PROCESS UNIT (INCREMENTS WRITE PROCESS)

WRITE REQUEST

wbid	Offset	WRITE DATA

S1901

wbid IS IN BID OF INCREMENTS MANAGEMENT TABLE 1300?

YES

NO

S1902

REGISTER wbid IN INCREMENTS MANAGEMENT TABLE 1300

S1903

READ WRITE DESTINATION BLOCK OF LV2

S1904

WRITE IN INCREMENTS-VOLUME

END

FIG. 19

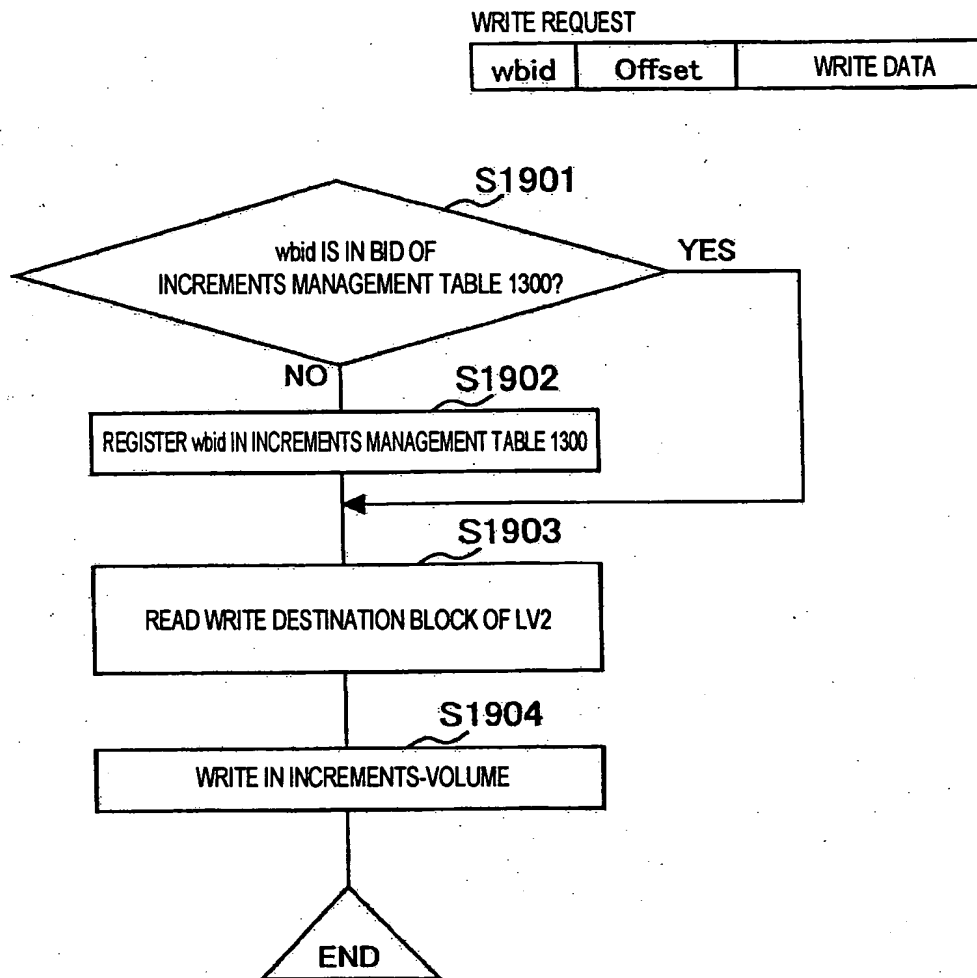Robert C. Colwell, Reg. No. 27,431   (650) 326-2400
Applicant: Aki TOMITA
Title: DATA I/O SYSTEM USING A PLURALITY OF MIRROR...
Atty Docket No. 16869K-109000US
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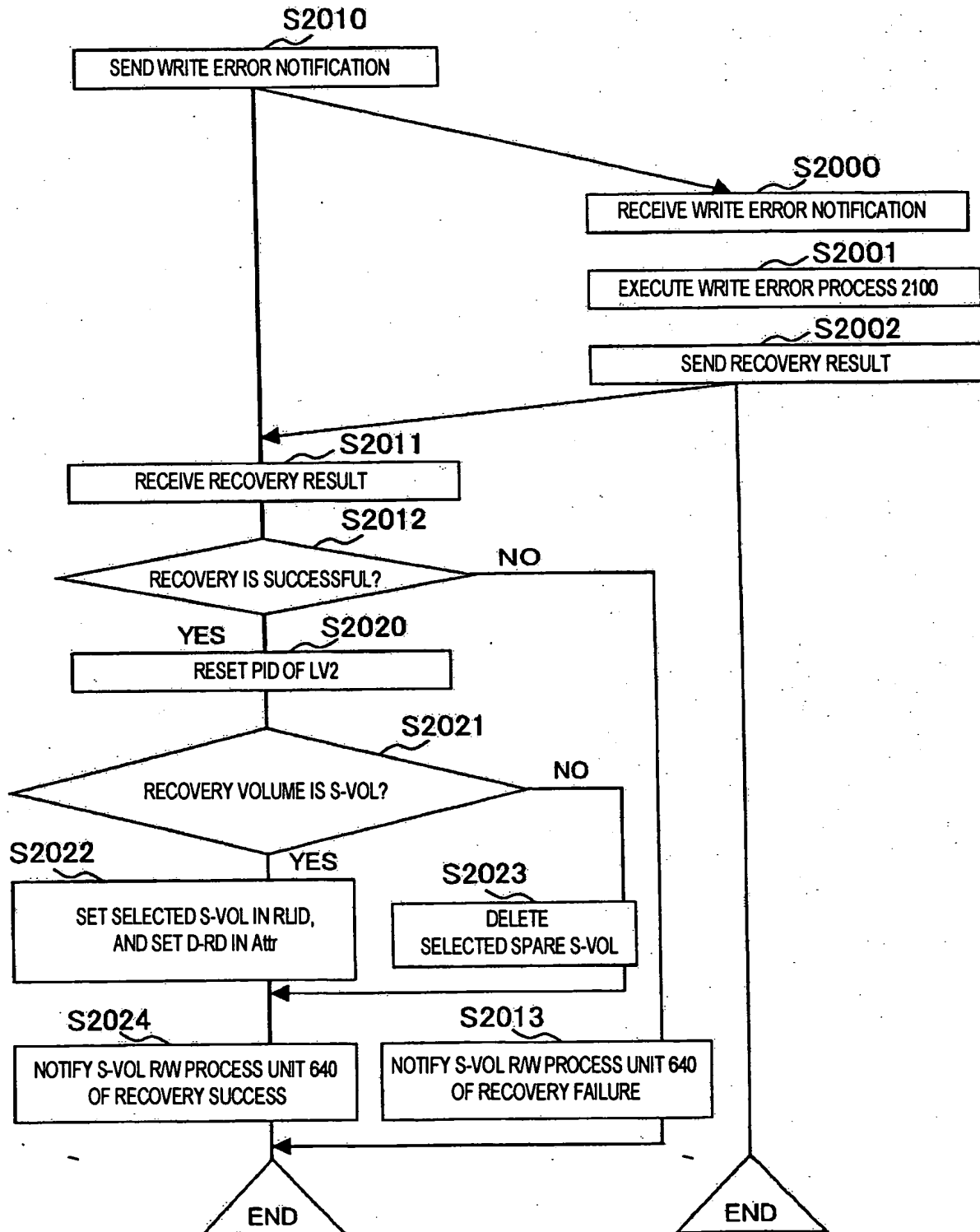S-VOL ERROR PROCESS UNIT 650   S-VOL GROUP MANAGEMENT UNIT 620

S2010
SEND WRITE ERROR NOTIFICATION

S2000
RECEIVE WRITE ERROR NOTIFICATION

S2001
EXECUTE WRITE ERROR PROCESS 2100

S2002
SEND RECOVERY RESULT

S2011
RECEIVE RECOVERY RESULT

S2012
RECOVERY IS SUCCESSFUL?   NO

YES   **S2020**
RESET PID OF LV2

S2021
RECOVERY VOLUME IS S-VOL?   NO

S2022   YES   **S2023**
SET SELECTED S-VOL IN RLID,   DELETE
AND SET D-RD IN Attr   SELECTED SPARE S-VOL

S2024   **S2013**
NOTIFY S-VOL R/W PROCESS UNIT 640   NOTIFY S-VOL R/W PROCESS UNIT 640
OF RECOVERY SUCCESS   OF RECOVERY FAILURE

END   END

FIG. 20

Robert C. Colwell, Reg. No. 27,431   (650) 326-2400
Applicant: Aki TOMITA
Title: DATA I/O SYSTEM USING A PLURALITY OF MIRROR...
Atty Docket No. 16869K-109000US
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S-VOL WRITE ERROR PROCESS

S2101

SPARE S-VOL IS PRESENT?

YES

NO

S2102

RO S-VOL IS PRESENT?

NO

YES

S2110

CHANGE PID TO PID OF SPARE S-VOL

S2103

NOTIFY WRITE ERROR

S2111

DELETE SPARE S-VOL

S2104

INQUIRE SA 230 OF Freq OF RO S-VOL

S2105

SELECT RO S-VOL BASED ON Freq

S2106

CHANGE PID TO PID OF SELECTED S-VOL, AND CHANGE Attr TO D-RW

S2107

REGISTER LID OF SELECTED S-VOL IN RLID

END

FIG. 21

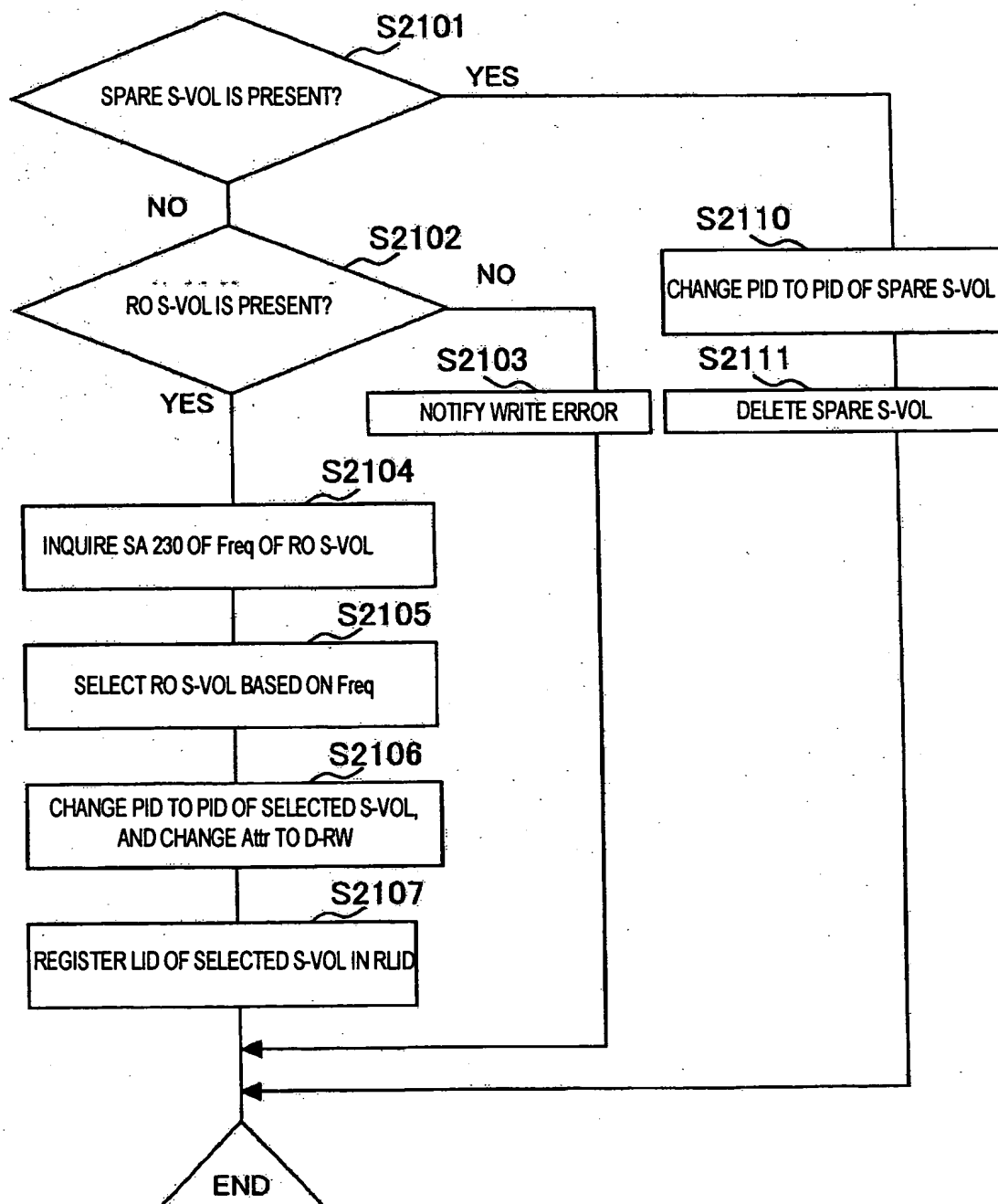Robert C. Colwell, Reg. No. 27,431   (650) 326-2400

Applicant: Aki TOMITA
Title: DATA I/O SYSTEM USING A PLURALITY OF MIRROR...
Atty Docket No. 16869K-109000US
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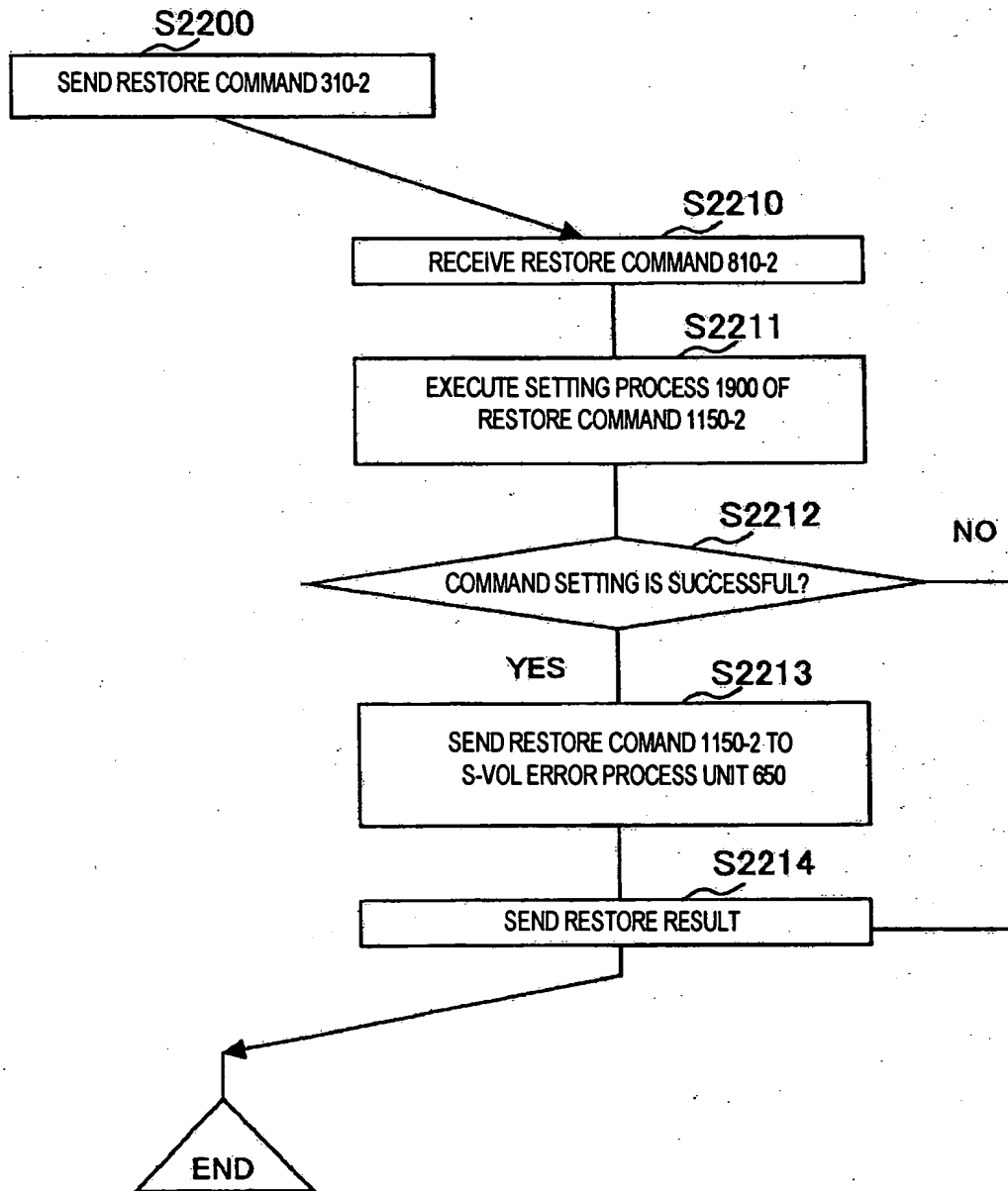S-VOL GROUP SETTING UNIT 610   S-VOL GROUP MANAGEMENT UNIT 620

S2200

| SEND RESTORE COMMAND 310-2 |

S2210

| RECEIVE RESTORE COMMAND 810-2 |

S2211

| EXECUTE SETTING PROCESS 1900 OF RESTORE COMMAND 1150-2 |

S2212

COMMAND SETTING IS SUCCESSFUL?   NO

YES   **S2213**

| SEND RESTORE COMAND 1150-2 TO S-VOL ERROR PROCESS UNIT 650 |

S2214

| SEND RESTORE RESULT |

END

FIG. 22

Robert C. Colwell, Reg. No. 27,431   (650) 326-2400

Applicant: Aki TOMITA
Title: DATA I/O SYSTEM USING A PLURALITY OF MIRROR...
Atty Docket No. 16869K-109000US
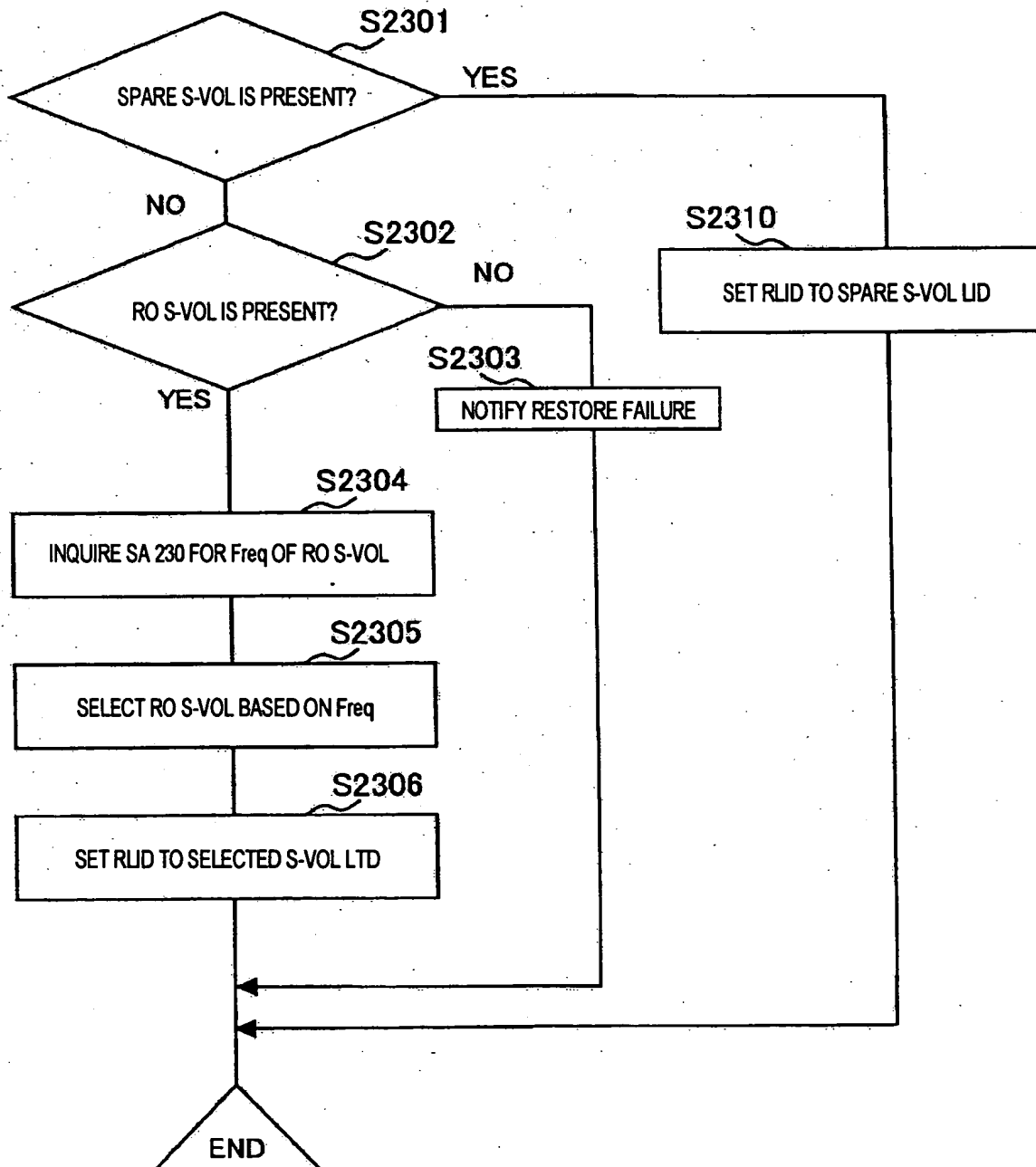**Sheet 20 of 21**

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RESTORE COMMAND SETTING PROCESS

FIG. 23

Robert C. Colwell, Reg. No. 27,431   (650) 326-2400

Applicant: Aki TOMITA
Title: DATA I/O SYSTEM USING A PLURALITY OF MIRROR...
Atty Docket No. 16869K-109000US
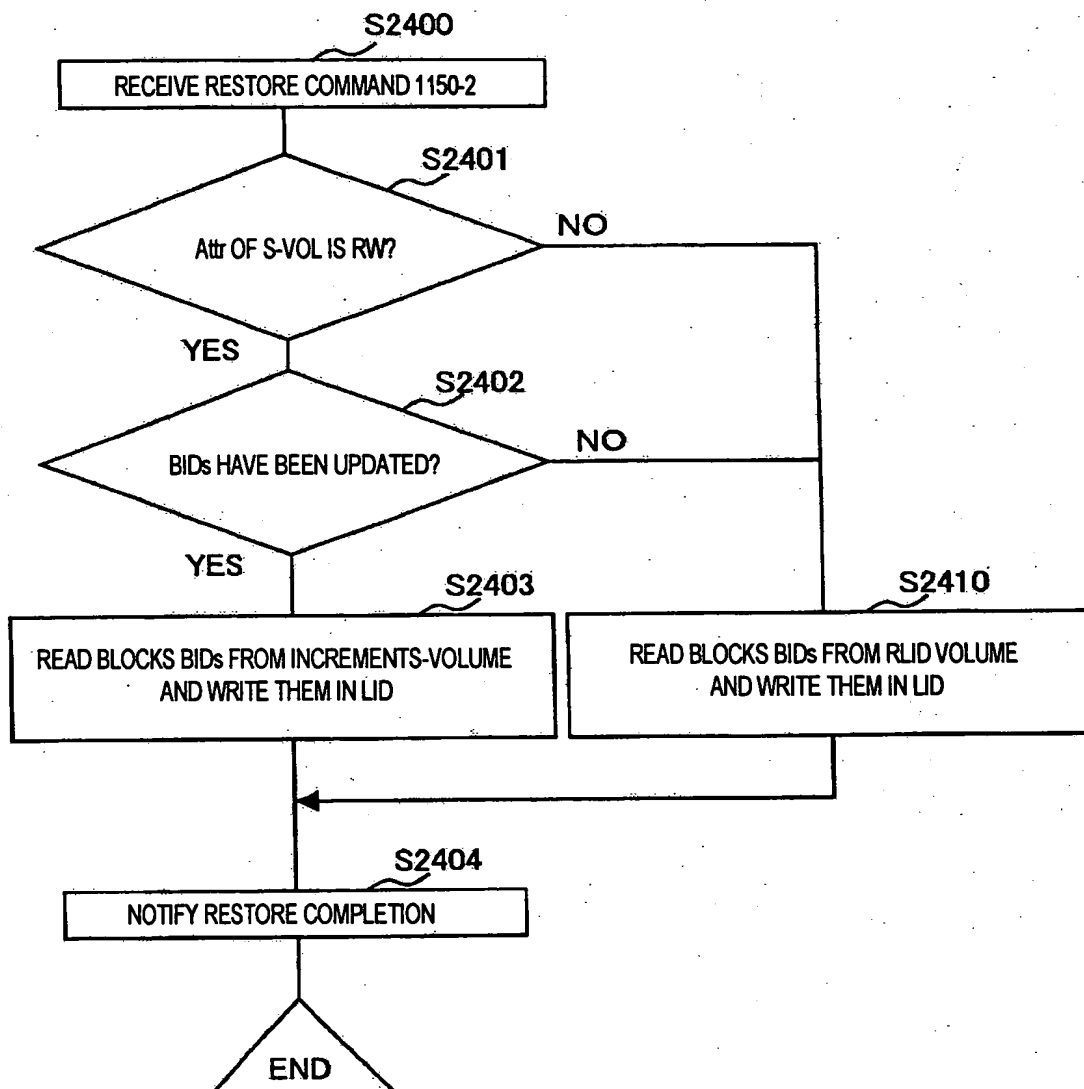**Sheet 21 of 21**

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S-VOL ERROR PROCESS UNIT

S2400

RECEIVE RESTORE COMMAND 1150-2

S2401

Attr OF S-VOL IS RW?   NO

YES

S2402

BIDs HAVE BEEN UPDATED?   NO

YES

S2403
READ BLOCKS BIDs FROM INCREMENTS-VOLUME AND WRITE THEM IN LID

S2410
READ BLOCKS BIDs FROM RLID VOLUME AND WRITE THEM IN LID

S2404
NOTIFY RESTORE COMPLETION

END

FIG. 24